ANALYSIS OF A SPUR GEAR IN AUTOMOTIVE SYSTEM USING FINITE ELEMENT SOFTWARE

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ABSTRACT

This study applied the Numerical Method Model to determine a characteristic for system gear. The most critical components in power transmission system are gearing system because in automotive industry gearing is commonly used in machines. In this study, Finite Element Method was used to analyze gears system. A metal-type material that was used to analyze was two different materials. The first one is gray cast iron because this metal is widely used in industry and the second one is steel 4130 or alloy steel that to know either this material suitable using in gearbox. Gear will be study in static structure condition to determine a stress, strain and also displacement to know which gear got maximum impact for every components gear system. For this analysis used the gearing in gearbox system, with different size, weight, and shape. Before analysis is done, a gear system was modeled/designed using the SolidWork software. Every each gear are draw only using SolidWork because SolidWork were very flexible to design anything with any direction (3D). This software was used for determine a stress, strain, and displacement in the meshing model condition. From the FEM analysis result at every component gear, it was found at gear six for Driven and at gear one for Driver that got highest value stress, strain and displacement at 1000 rpm. So different materials maximum impact at same place for stress, strain and displacement but their value is not same, for gray cast iron the maximum stress is 4397.26 N/mm^2 (driven) and 6471.42 N/mm^2 (driver). For alloy steel the maximum stress is 4329.62 N/mm^2 (driven) and 4735.89 N/mm^2 (driver). Conclusion is if the speed in term revolution per minute is low, so the stress, strain and also displacement value will be high for static studies.

ABSTRAK

Kajian ini menggunakan Model Kaedah Berangka adalah untuk menentukan sifat yang terdapat pada system gear. Gear merupakan komponen yang paling kritikal dalam system pemindahan kuasa kerana sistem gear banyak digunakan dalam mesin-mesin didalam industri automotif. Dalam kajian ini, system gear akan dianalisa dengan menggunakan “Finite Element Software”. Bahan yang digunakan untuk dianalisa adalah daripada bahan yang berlainan. Yang pertama adalah besi tuang kelabu kerana besi ini kebiasaan digunakan dalam industry dan yang kedua adalah besi 4130 atau dikenali sebagai besi aloi untuk menentukan samaada bahan tersebut lebih sesuai digunakan dalam system gearbox. Pertama gear akan dikaji dalam kedudukan statik untuk menentukan tegasan, terikan dan juga perubahan ukuran untuk mendapatkan gear yang mana mendapat kesan paling tinggi. Sistem gearbox menggunakan gear dengan saiz, berat dan bentuk yang berlainan sama sekali. Sebelum kajian dibuat sistem gear perlu dilukis dengan menggunakan perisian “SolidWork”. Setiap gear dihasilkan dengan menggunakan perisian tersebut ini kerana perisian tersebut sangat berkebolehan dalam melukis dari perbagai arah (3D). Perisian ini adalah untuk mendapatkan tegasan, terikan dan juga perubahan ukuran. Daripada kajian FEM pada setiap gear, didapati Gear Enam (driven) dan juga Gear Satu (driver) yang mendapat nilai yang paling tinggi iaitu tegasan, terikan dan juga perubahan ukuran pada 1000 rpm. Jadi bahan yang berlainan mendapat nilai paling tinggi pada kedudukan yang sama tetapi nilainya tidak sama, tegasan untuk bahan besi tuang kelabu adalah 4397.26 N/mm^2 (driven) dan 6471.42 N/mm^2 (driver), manakala tegasan tertinggi untuk bahan besi aloi adalah 4329.62 N/mm^2 (driven) dan 4735.89 N/mm^2 (driver). Sebagai penutup jika kelajuan dari segi putaran per minit adalah perlahan, iaitu tegasan, terikan dan juga perubahan ukuran akan mendapat nilai yang tinggi untuk kajian static .

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Gear drivers are used to transmit power from one machine to another where changes of speed, torque, direction or rotation or shaft orientation are required. They may consist of one or more sets of gears depending on the requirements. In most cases the gears are mounted on shaft supported by an enclosed casing which also contains a lubricant.

The rotation of one gear causes the opposite rotation of the meshing gear. The smallest gear is called pinion gear. When two gears are meshing together, one gear is rotating clockwise and can cause the other gear to rotate counterclockwise. An added third gear are rotate same with gear one and forth gear are rotated same with gear two.

Gear of equal diameter have a 1:1 ratio and rotate at the same rate. For example, a complete revolution of gear A produces a complete revolution of gear B, if gear A is one-half the diameter of gear B, the larger gear B revolves 180 degree or half a revolution for every of gear A. gear A turns two revolution for one revolution Of gear B. gear A and B have a 2:1 ratio. The ratio is determined by dividing the large gear pitch diameter by the small gear pitch diameter.

Gears are designed to have backlash between meshing teeth for maximum life and efficiency. Backlash is the amount of movement or play between the meshing teeth of gears. Backlash result when the tooth space exceeds the meshing tooth. Backlash is required between meshing gears to prevent full contact on both sides of teeth. The space created allows lubricant between the contacting surfaces.

Too little backlash can causes undesirable resistance resulting in the overheating or jamming of the meshing gears. Lubricant can become trapped at the base of tooth. Excessive backlash can also cause problems if the load is reversed frequently.

1.2 PROBLEM STATEMENT

All machine have their own problem or can say their advantages, so gearbox of motorcycle also have their weakness either because of human or span life the gearbox. In previous research has found that noise, vibration, and overheating currently happen in gearbox. This problem actually almost happen every gearbox, and will effect to the gear either in term speed, velocity and transfer power from one shaft to another shaft.

1.3 OBJECTIVE

i. Study about static of spur gear in gearbox system.
ii. Analyze which a spur gear in gearbox got highest impact (Driven and Driver)
iii. Choice the best material for spur gear in gearbox system

1.4 SCOPE

i. Drawing the spur gear in gearbox system using the cad software.
ii. Analyze the spur gear for gearbox system with cad software.
iii. Find the stress, strain, and displacement of spur gear (gearbox component) from cad software in static studies.
iv. Find highest impact for spur gear (Driven and Driver)
v. Choose the best material using for spur gear.

1.5 TYPE AND ARRANGEMENTS

The following types of gears in common use.

1.5.1 Spur gear.

The spur gear is the simplest type of gear and they have straight teeth and only can function on parallel shafts operating at modern speeds. Spur gear may be used as external or internal gears or as rack and pinion. They are simple to manufacture, less cost and also durable. The large gear called the wheel or bull gear and the smaller one the pinion. This gear is used in many devices like electric screwdriver, mechanical machine, and many more in automotive industry.

Figure 1.1: Spur gear

1.5.2 Helical and herringbone gears.

The helical gears are also used to transmit power between parallel shafts but teeth are cut on an angle. Their advantage over the helical gears is that the side-thrust of one half is balanced by that of the other half. Because of the angle of the teeth, helical gars produce end thrust which must be carried by the shaft bearings. This can be overcome by the use of two rows of opposed helical teeth in a 'herringbone' arrangement.

Figure 1.2: Helical and herringbone gears

1.5.3 Bevel gears

The bevel gears are used to transmit power between two intersecting shafts, also used to change the direction of drive in a gear system by 90 degrees. The teeth on bevel may be plain or spiral. The beveled design allows the gear to intermesh with another bevel gear at several different angles, it depending on how it has been machined.

Figure 1.3: Bevel gears

1.5.4 Hypoid gears

Gear bevel gear resembling in shape but are designed to mesh with the same gear in such a way that their axes are not met, the other crossing the axis at approximately right angles.

Figure 1.4: Hypoid gears

1.5.5 Worm gears

The worm gears are designed to transmit motion between nonintersecting perpendicular shafts at right angles and are used when high ratio speed reduction is required. The worm is always the drive gear.

Whatever type of gear is employed, the arrangement may involve one or more pairs of gears depending on the degree of speed reduction required.

Most gear drivers are mounted in fully enclosed casings but large ring gears may be installed as open gears with a suitable guard arrangement. To increase the wear resistance the gear is made from steel or cast iron.

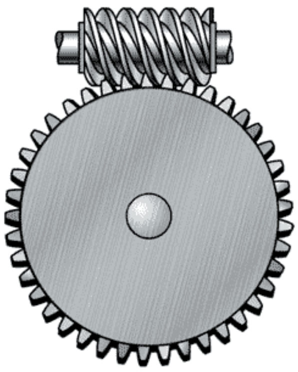

Figure 1.7: Worm gears

1.6 MAINTENANCE PRACTICES

Like other methods of transmission, the key to a satisfactory operating gear drive is alignments, proper lubrication and exclusion dirt and other contaminants.

1.6.1 Alignment

In the spur gear alignment is determined by machining casing and bearing housing and gear under normal circumstances should be automatically aligned. Care should be taken when fitting the gearbox to ensure that no irregularities occur when the bolt casing plunger is pulled down. Excessive wear on the bearings and walk out will lead the way out and gear tooth wear and should be corrected as soon as possible.

When open the gear, gear can be measured by using the specific measurement to align the gear misalignment, wheatear center distance of gear or the reaction between the teeth can be measured.

If want the alignment gear more accurate can used a feeler gauge. Supervision must be taken, when the relative position of the gears adjusted, to ensure that it remains parallel to the gear shafts run true. Parallel alignment of face gear teeth can be checked by using a blue mark on the pinion gear and then rotate the gear wheel over by hand. Gear wheel tooth contact patterns have even across the face.

1.6.2 Lubrication

Gearbox bearing lubricant reservoir in the lower part of the gear sink. As they take turns gear lubricants that protect teeth during contact. If the maximum gear life is to be achieved the correct lubricant must be used and the correct operation must be maintained in the reservoir or sump.

A gear box should be checked for leakage current and need to be corrected as soon as possible. Products put on the gear teeth will collect the oil reservoir in conjunction with any other combinenates into gear glove box. Therefore, it is necessary to change the lubricant at regular periods or around 5000km as recommended by the manufacturer.

This is especially important during the run-in phase of the machine when the rate of production of wear debris tends to be quite high.

The pressure-lubricated gearbox is usually installed with a filter and this must change or cleaned regularly. Open gear usually lubricated by the gear sump where cattle run. If the atmosphere is so great task build-up can occur in gear and it needs to be cleaned from time to time.

1.7 OPERATING SYMPTOM

The symptoms of gear can easily detectable by gear malfunction during operation are relatively few in number easily detectable.

i. Noise

Even gears are in good condition also having their own tone or noise. This is happen cause by the continuous impact of the gear teeth as they mesh with each other and it varies with speed and torque transmitted. Every gear combination when their meshing two gears are make sound with lubrication in the gearbox could reduce the noise.

Gears are in good condition should produce a constant hum and low sound with a relatively smooth tone. Once the gears begin to deteriorate, or some malfunction in their operation develops, this noise will change. The sound may become much rougher which could indicate that the gears are not properly in mesh warn out or are out of alignment.

ii. Vibration

All components gear has movement of vibration. An increase in vibration levels will occur when condition deteriorates or malfunction develops. The most likely causes of an increase in vibration levels are shaft misalignment ant teeth running out of mesh. This maybe happen when assembly between the shaft. Wear and deterioration of tooth surface condition, unless they become excessive, are less likely to cause an increase in vibration levels.

iii. Overheating

Overheating of gearbox maybe happen when gearbox is leaking or less lubricant. Other is misalignment or running unstable also can make the gearbox overheating. These condition can be detect when change of noise and also the vibration.

1.8 CAUSES

(i) Inadequate lubrication

The operation of gears is vitally dependent on an adequate supply of the correct lubricant and if this enough oil for gearbox should give almost unlimited life. If the mistaken lubricant is used or if lubricant is allowed to deteriorate the gears will begin to wear. It is also important that lubricant be changes if the lubricant are recommendation by the. Additives should be carefully selected to suit the particular operating conditions and lubricant supply systems, including filters, should be properly maintained.

(ii) Misalignment

There are two types of misalignments that could happen. They may be out of parallel or out of plane. The uneven wear patterns referred to in the previous section are produced by misalignment and if the condition is allowed to continue the tooth breakage may eventually occur.

(iii) Out of mesh

If the gears that set up to touch each other but when it not touching each other they can be considered to be out of mesh. If the center distance between the gears is too small and there is insufficient backlash then interference occurs and the tip of one tooth tends to dig into the root the mating tooth and produce excessive wear. This will cause rapid deterioration of gear condition and may result in excessive noise and vibration. If gears are set too far apart the backlash will be excessive and wear will occur close to the teeth which may, even break from the impact. Noise and vibration will also increase due to large amount of backlash.

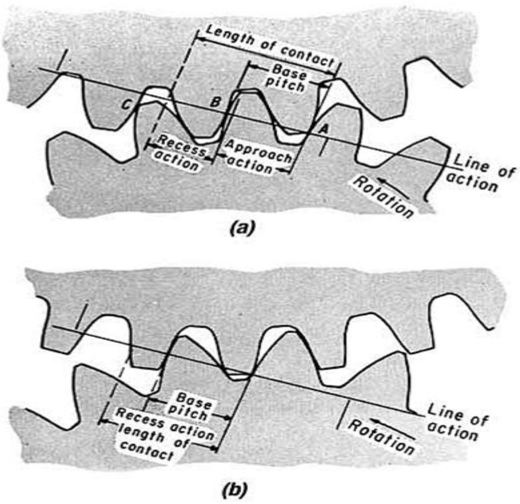

Figure 1.8: Gears out of mesh.

(iv) Overload

Speeds and load which exceed design limits and high impact loads will accelerate wear processes and lead to the like hood of premature failure. Heavy spalling or galling and tooth breakages are the usual consequences of overload conditions. The design limits of the drive should be checked and the unit operated according to the manufacturer's instructions.

(v) Contamination

The contamination of gear lubricant due to the presence of dirt, dust or other abrasives also will increase wear rates and causes damages of tooth surface. Particles of wear metal or chips of broken teeth will also cause significant damage. More attention should give to the condition of seals and filters to replacement if lubricant of contamination is to be avoided.

(vi) Moisture

The presence of moisture in a gear box may cause rusting to develop. In order to avoid moisture due to condensation build-up, special breather arrangements may be required whereas ingress of moisture from other sources should be prevented by the oil seals.

(vii) Lubricant breakdown

If lubricants are not replaced at exactly time they may deteriorate to the point where harmful acids may form. If corrosion is detected stroke lubricant analysis may be required to establish whether any change in properties of the lubricant has occurred. The effect of lubricant additives on particular metals should also be considered and the lubricant manufacturer consulted for advice.

CHAPTER 2

LITERATURE REVIEW

2.1 OVERVIEW

Gears are one of the critical components in industrial rotating machinery. There is a vast amount of literature on gear modeling. The objective in static modeling of gears is varied from overheating, vibration analysis and also noise of gearbox, to transmission errors and stability analysis over at least the past five decades. All goals for these analyses are almost same to define the following study.

(i) Stress analysis such as bending and contact stresses,
(ii) Reduction of surface pitting and scoring,
(iii) Natural frequencies of the system,
(iv) Vibration motion of the system,
(v) Reliability and fatigue life
(vi) Loads on the other machine elements of the system especially on bearings and their stability regions.

In the solution of the system equations, numerical techniques have usually been used. Although most of the models for which numerical techniques are used are lumped parameter models, some investigators have introduced continuous system or finite element models. While closed form solutions are given for some simple mathematical models, numerical computer solutions have sometimes been preferred for non-linear and more complicated models, particularly in the earlier studies.

The models proposed by several investigators show considerable variations not only in the effects included, but also in the basic assumptions made. Although it is quite difficult to group the mathematical models developed in gear dynamics, Ozguven and Houser (Ozguven 1988; Ozguven 1988) have presented a thorough classification of gear dynamic mathematical models. In 1990, Hauser (Hauser 1990) and Zakrajsek et al. (Zakrajsek 1990) autlined the past and current research projects of gear dynamics and gear noise at Ohio State University's Research Laboratory and NASA Lewis Research Centre respectively, Du (Du 1997) also classified various gear dynamic models into groups.

The current literature review also attempts to classify gear dynamic models into groupings with particular relevance to the research presented in this thesis. It is possible for some models to be considered in more than one grouping, and so the following classification seems appropriate.

Models with Tooth Compliance, there are a very large number of studies that include the tooth stiffness as the only potential energy storing element in the system. This group includes single tooth models and tooth pair models. For single tooth models, the objectives usually are tooth stress analysis. For the models with a pair of teeth, the focuses mostly are contact stress and mesh stiffness analysis. That is the flexibility (torsional and/or transverse) of the shafts, bearings, etc, is all neglected. In such studies the system is usually modeled as a single degree of freedom spring-mass system. Some of the models have also been analyzed using the Finite Element Method.

In other studies the main objective has been to find the mode shapes and system natural frequencies and, therefore, only free vibration analyses can made. However, usually the dynamic response of the system is analyzed for a defines excitation. In most of me studies the response of the system to forcing due to gear errors and to parametric excitation due to tooth stiffness variation during the tooth contact cycle is determined. The models constructed to study, the excitations due to gear errors and/or tooth stiffness variation provide either a transient vibration analysis or a harmonic vibration analysis by first determining the Fourier series coefficients of the excitation. Some studies also include the non-linear effect caused by loss of tooth contact or by the friction between meshing teeth. The excitation is then taken as an impact load and a transient vibration analysis is made.

2.2 GEAR MODELING

Numerous mathematical models of gears have been developed for different purposes, the basic characteristics of each class of dynamic models along with the objective and different parameters considered in modeling have been discussed in section 2:1. This section presents a review of papers published in the areas outlined above, including brief information about the models and the approximations and assumptions made.

2.2.1 Models with tooth Compliance

The basic characteristic of the models is the group is that the only compliance considered is due to the gear tooth and that at other elements have been assumed to be perfectly rigid. The model is either a single model or a tooth pair model. For single tooth models, the objectives usually are tooth stress analysis. For models with a pair of teeth, the focus is mostly contact stree and meshing stiffness analysis. The resulting models are either translation or torsional. With torsional models one can study the torsional vibrations of gears. Where with translation models the tooth of gear is considered as one can study the forced vibrations of theeth. In either of those models the transmission error excitation is simulated by a displacement excitation at the gear mesh.

In 2006, Huseyin Imrek (Huseyin 1973) used a finite element model of a single tooth to analyses the effect of surface pressure distribution on wear after modifying gear teeth width. These studies found the amount of wear that is acceptable depends on the expected life, noise and vibration of the gear units, which this result in high loading and loss of tooth thickness, which may cause bending fatigue. This analysis is used same value for modified and unmodified. As conclusion is by wear imbalances formed as a result the instantaneous pressure increases on single and double meshing area can be reduces.

In 2007, Yilmaz Chan (Yilmaz 2007) studied the analysis of spur gear forms with tapered tooth profile. The research was focused on of the extrusion of spur gear forms and a comparative evaluation of the methods of lateral extrusion and closed die forging of spur gear forms in term of mechanical properties of the product. This analysis also applied the fatigue and hardness tests to gear teeth produced by both processes and there were applied in a manner of three point bending tests. Their result is the increasing number of teeth causes an increased in the number of shear surface, in the area of tool material contact surface and in the volume of the deforming materials.

In the late 1980s, Ramamurti and Rao (Ramamurti 1988) presented a new approach to the stress analysis of spur gear teeth using FEM. Their new approach, with a cyclic system of gear teeth and with asymmetry of the load on the teeth, allowed computation of the stress distribution in the adjacent teeth from the analysis of one tooth only. The boundary conditions imposed between the two adjacent teeth the conventional FEM were avoided in their approach.

In 2006, Tengjiao Lin, H. Ou and Runfang Li (Tengjiao 2006) an approach for mesh generation of gear drives at any meshing position is presented and an automatic modeling program for tooth mesh analysis. This method is also used to simulate the gear behavior under dynamic loading conditions. This analysis is used based on derivation of a flexibility matrix equation in the contact region, a finite element method for 3D contact/impact problem is proposed. This result for this analysis is the higher the rotating speed, the larger the total contact force and the increased values of the backlash and the total contact forces increases also the contact time

In 2006, a review of the machining errors, assembly errors, and tooth modifications compared to finite element analysis was given by Shuting Li (Shuting 2006). They presented an three-dimensional (3D) to conduct surface contact stress and root bending stress calculation of a pair of spur gears. Tooth contact lengths of a pair of spur gears with lead crowning are calculated by the programs and compared with the measured result. Their results showed that machining errors, assembly errors, and tooth modifications exert great effects on RBS and SCS. Since it is difficult thing to use ISO